FIG. 1

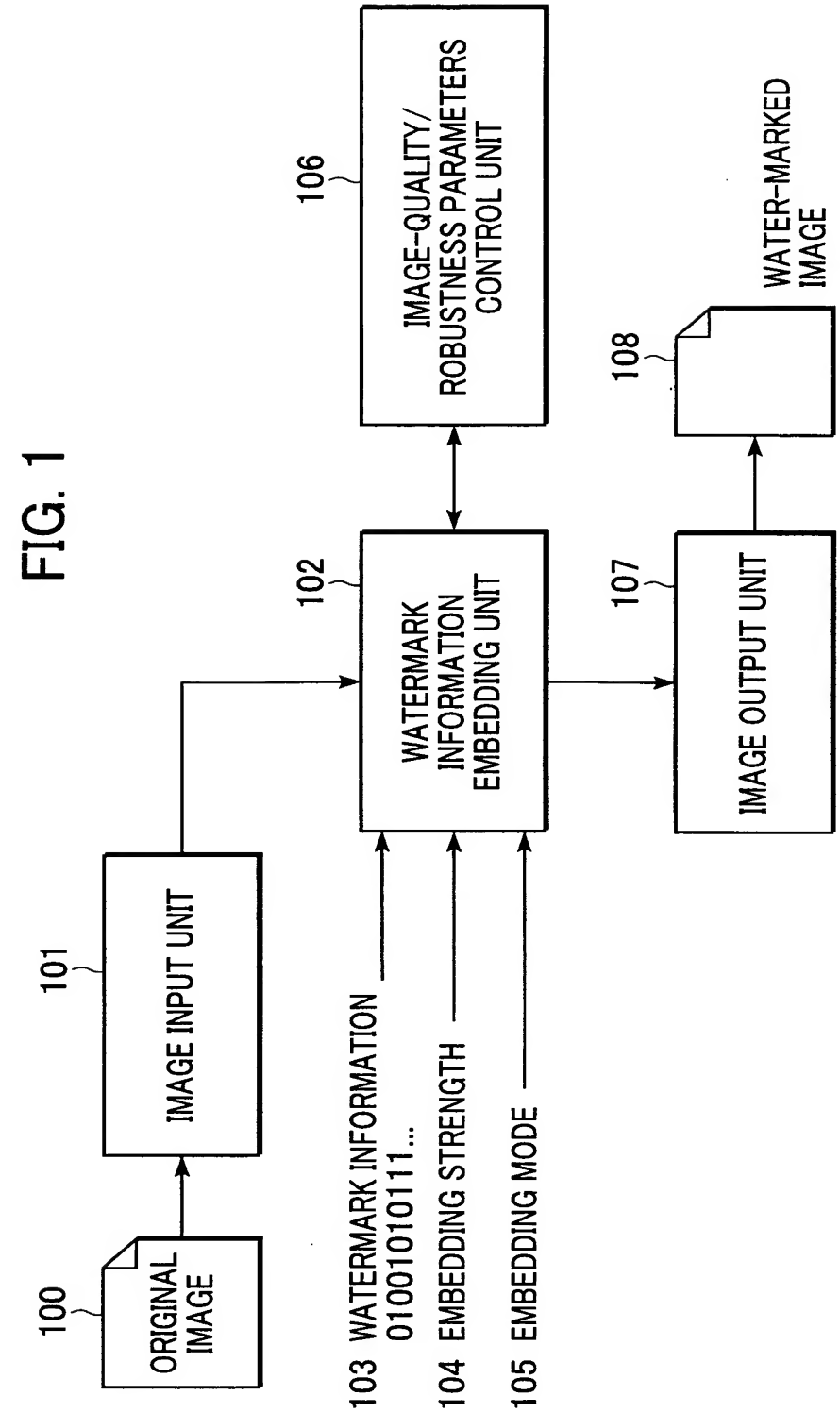

100
ORIGINAL IMAGE
101
IMAGE INPUT UNIT
102
WATERMARK INFORMATION EMBEDDING UNIT
103 WATERMARK INFORMATION 01001010111...
104 EMBEDDING STRENGTH
105 EMBEDDING MODE
106
IMAGE-QUALITY/ ROBUSTNESS PARAMETERS CONTROL UNIT
107
IMAGE OUTPUT UNIT
108
WATER-MARKED IMAGE

FIG. 2

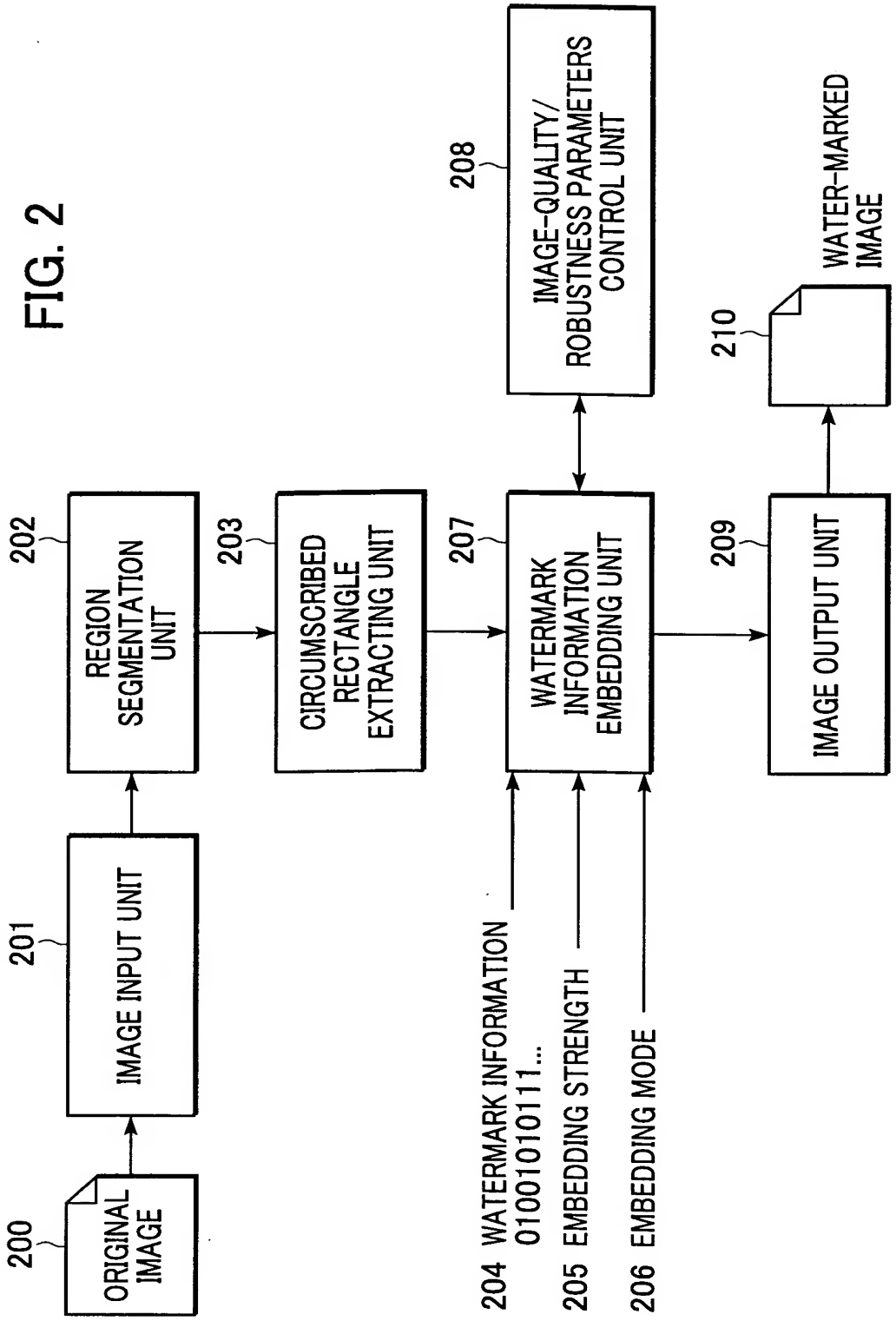

200
ORIGINAL IMAGE
201
IMAGE INPUT UNIT
202
REGION SEGMENTATION UNIT
203
CIRCUMSCRIBED RECTANGLE EXTRACTING UNIT
204 WATERMARK INFORMATION 01001010111...
205 EMBEDDING STRENGTH
206 EMBEDDING MODE
207
WATERMARK INFORMATION EMBEDDING UNIT
208
IMAGE-QUALITY/ ROBUSTNESS PARAMETERS CONTROL UNIT
209
IMAGE OUTPUT UNIT
210
WATER-MARKED IMAGE

FIG. 3

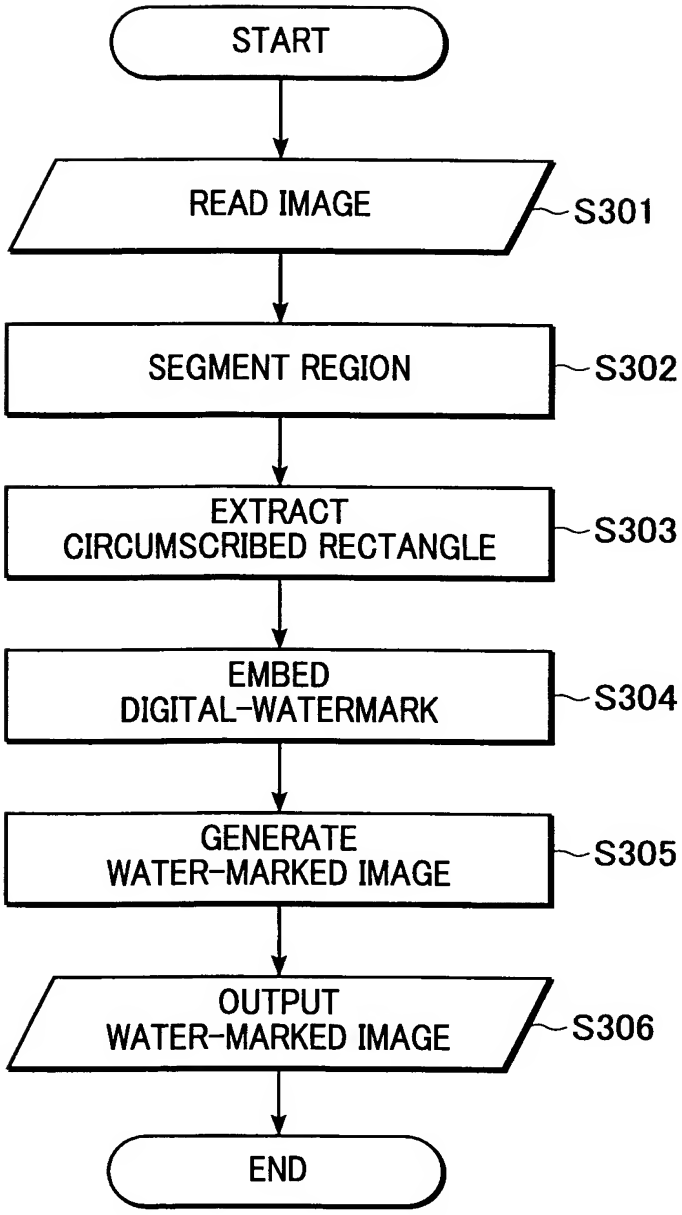

START
READ IMAGE
S301
SEGMENT REGION
S302
EXTRACT CIRCUMSCRIBED RECTANGLE
S303
EMBED DIGITAL-WATERMARK
S304
GENERATE WATER-MARKED IMAGE
S305
OUTPUT WATER-MARKED IMAGE
S306
END

FIG. 4

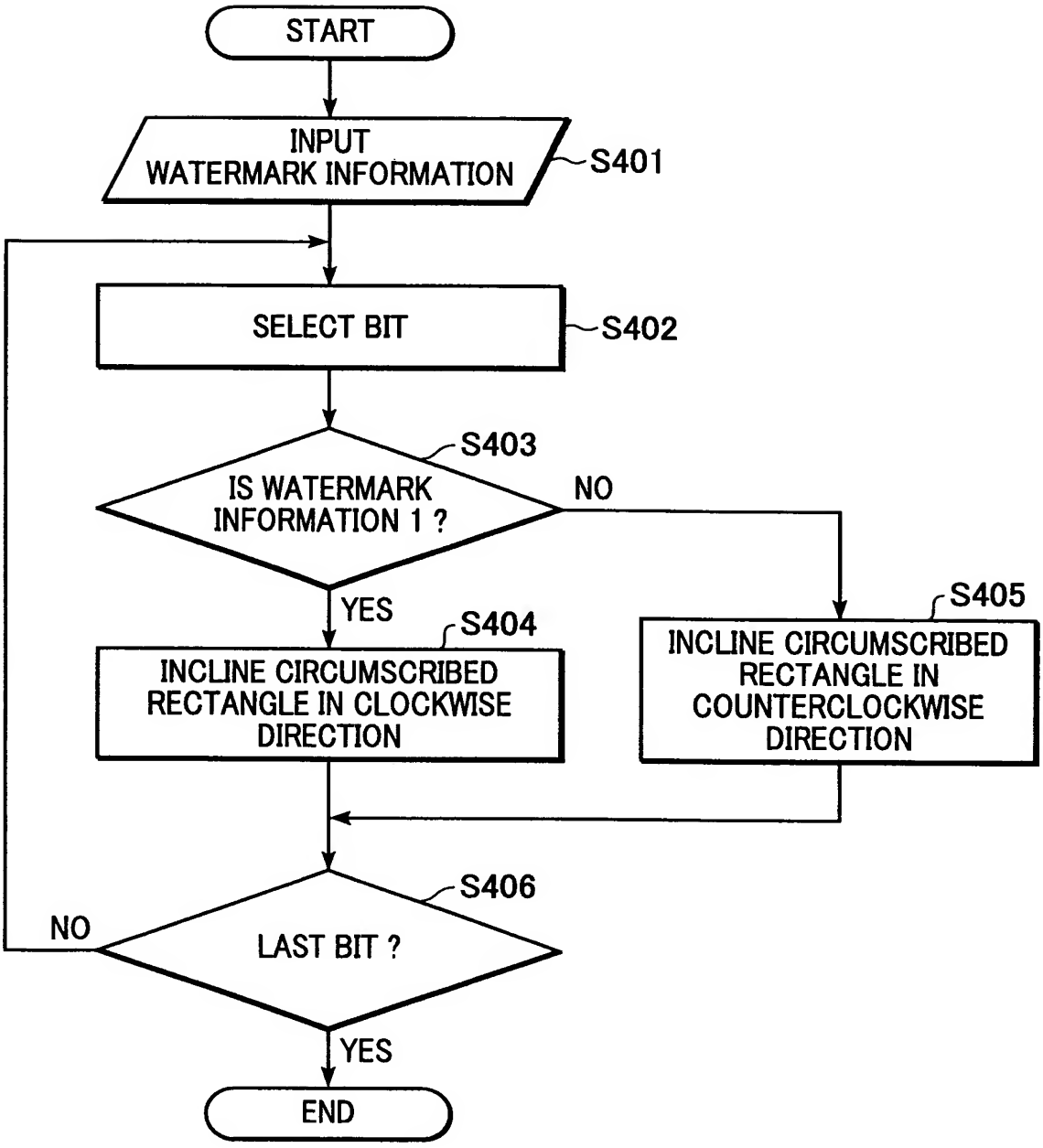

START
INPUT WATERMARK INFORMATION
S401
SELECT BIT
S402
S403
IS WATERMARK INFORMATION 1 ?
NO
YES
S404
INCLINE CIRCUMSCRIBED RECTANGLE IN CLOCKWISE DIRECTION
S405
INCLINE CIRCUMSCRIBED RECTANGLE IN COUNTERCLOCKWISE DIRECTION
S406
LAST BIT ?
NO
YES
END

FIG. 5

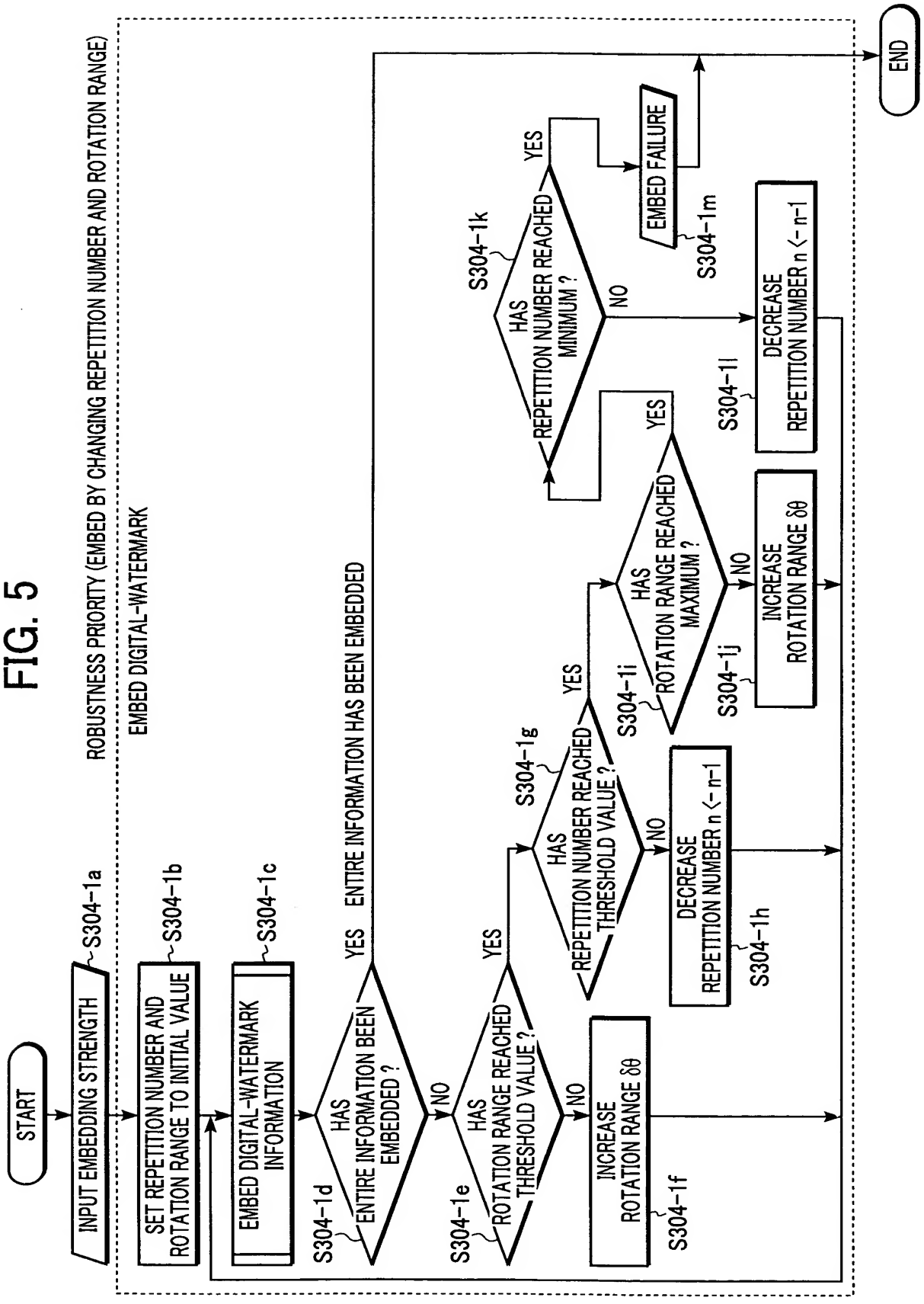

START
INPUT EMBEDDING STRENGTH
S304-1a
ROBUSTNESS PRIORITY (EMBED BY CHANGING REPETITION NUMBER AND ROTATION RANGE)
EMBED DIGITAL-WATERMARK
SET REPETITION NUMBER AND ROTATION RANGE TO INITIAL VALUE
S304-1b
EMBED DIGITAL-WATERMARK INFORMATION
S304-1c
S304-1d
HAS ENTIRE INFORMATION BEEN EMBEDDED ?
YES
ENTIRE INFORMATION HAS BEEN EMBEDDED
NO
S304-1e
HAS ROTATION RANGE REACHED THRESHOLD VALUE ?
YES
S304-1g
HAS REPETITION NUMBER REACHED THRESHOLD VALUE ?
YES
S304-1i
HAS ROTATION RANGE REACHED MAXIMUM ?
YES
S304-1k
HAS REPETITION NUMBER REACHED MINIMUM ?
YES
EMBED FAILURE
S304-1m
NO
S304-1l
DECREASE REPETITION NUMBER n <- n-1
NO
S304-1j
INCREASE ROTATION RANGE δθ
NO
DECREASE REPETITION NUMBER n <- n-1
S304-1h
NO
INCREASE ROTATION RANGE δθ
S304-1f
END

FIG. 6

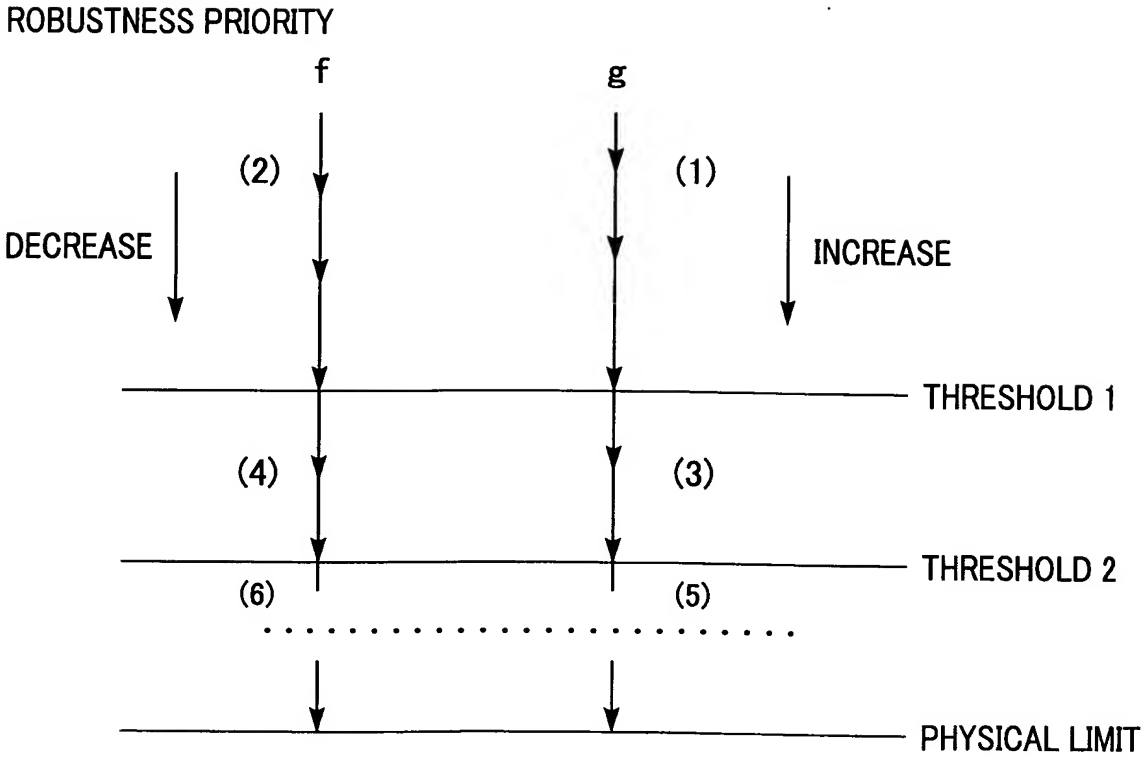

ROBUSTNESS PRIORITY
f
g
(2)
(1)
DECREASE
INCREASE
THRESHOLD 1
(4)
(3)
THRESHOLD 2
(6)
(5)
PHYSICAL LIMIT

FIG. 7

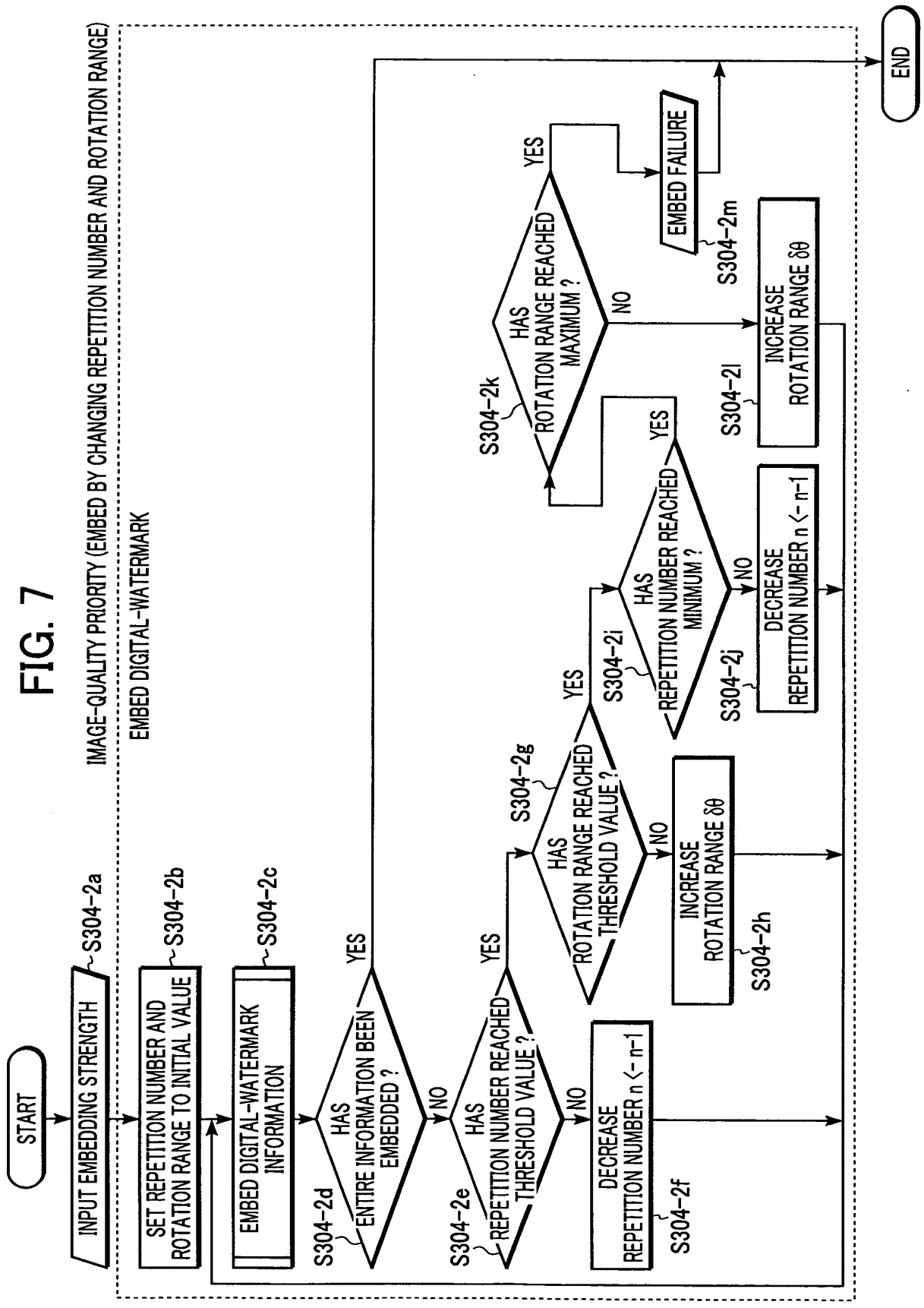

START
INPUT EMBEDDING STRENGTH
S304-2a
IMAGE-QUALITY PRIORITY (EMBED BY CHANGING REPETITION NUMBER AND ROTATION RANGE)
SET REPETITION NUMBER AND ROTATION RANGE TO INITIAL VALUE
S304-2b
EMBED DIGITAL-WATERMARK
EMBED DIGITAL-WATERMARK INFORMATION
S304-2c
S304-2d
HAS ENTIRE INFORMATION BEEN EMBEDDED ?
YES
NO
S304-2e
HAS REPETITION NUMBER REACHED THRESHOLD VALUE ?
YES
NO
DECREASE REPETITION NUMBER n <- n-1
S304-2f
S304-2g
HAS ROTATION RANGE REACHED THRESHOLD VALUE ?
YES
NO
INCREASE ROTATION RANGE δθ
S304-2h
S304-2i
HAS REPETITION NUMBER REACHED MINIMUM ?
YES
NO
S304-2j
DECREASE REPETITION NUMBER n <- n-1
S304-2k
HAS ROTATION RANGE REACHED MAXIMUM ?
YES
NO
S304-2l
INCREASE ROTATION RANGE δθ
EMBED FAILURE
S304-2m
END

FIG. 8

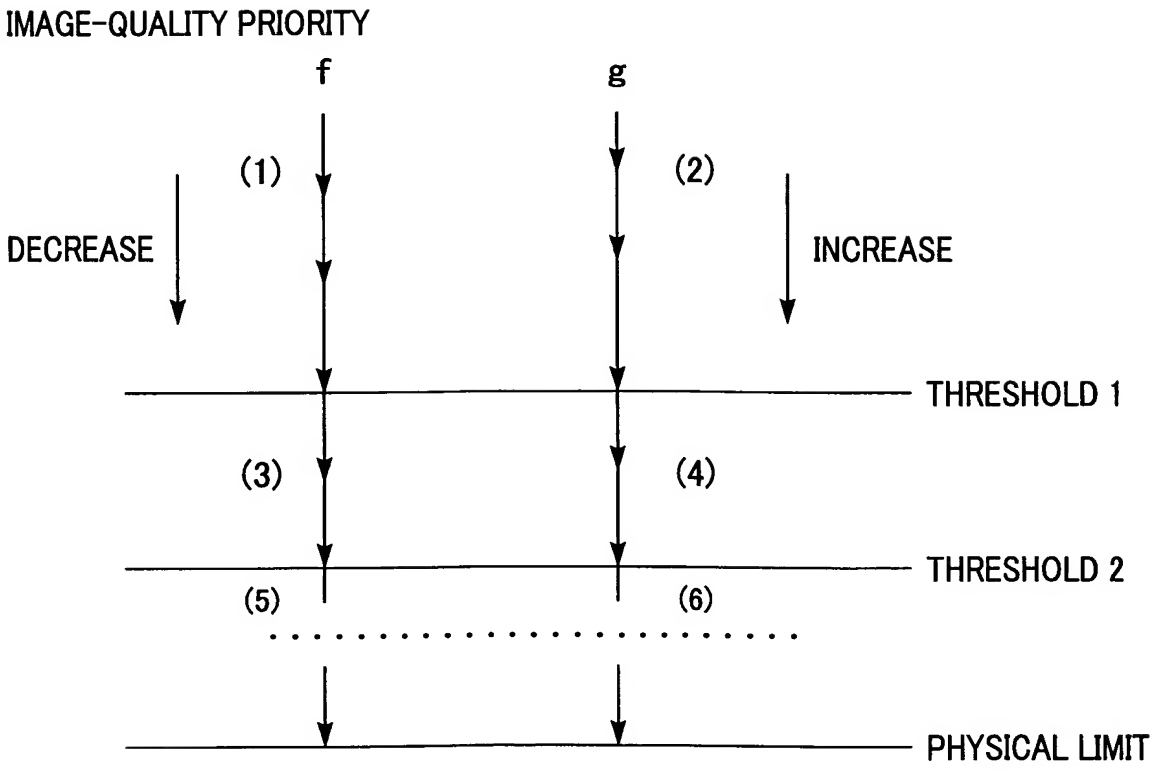


IMAGE-QUALITY PRIORITY
f
g
(1)
(2)
DECREASE
INCREASE
THRESHOLD 1
(3)
(4)
THRESHOLD 2
(5)
(6)
PHYSICAL LIMIT

FIG. 9

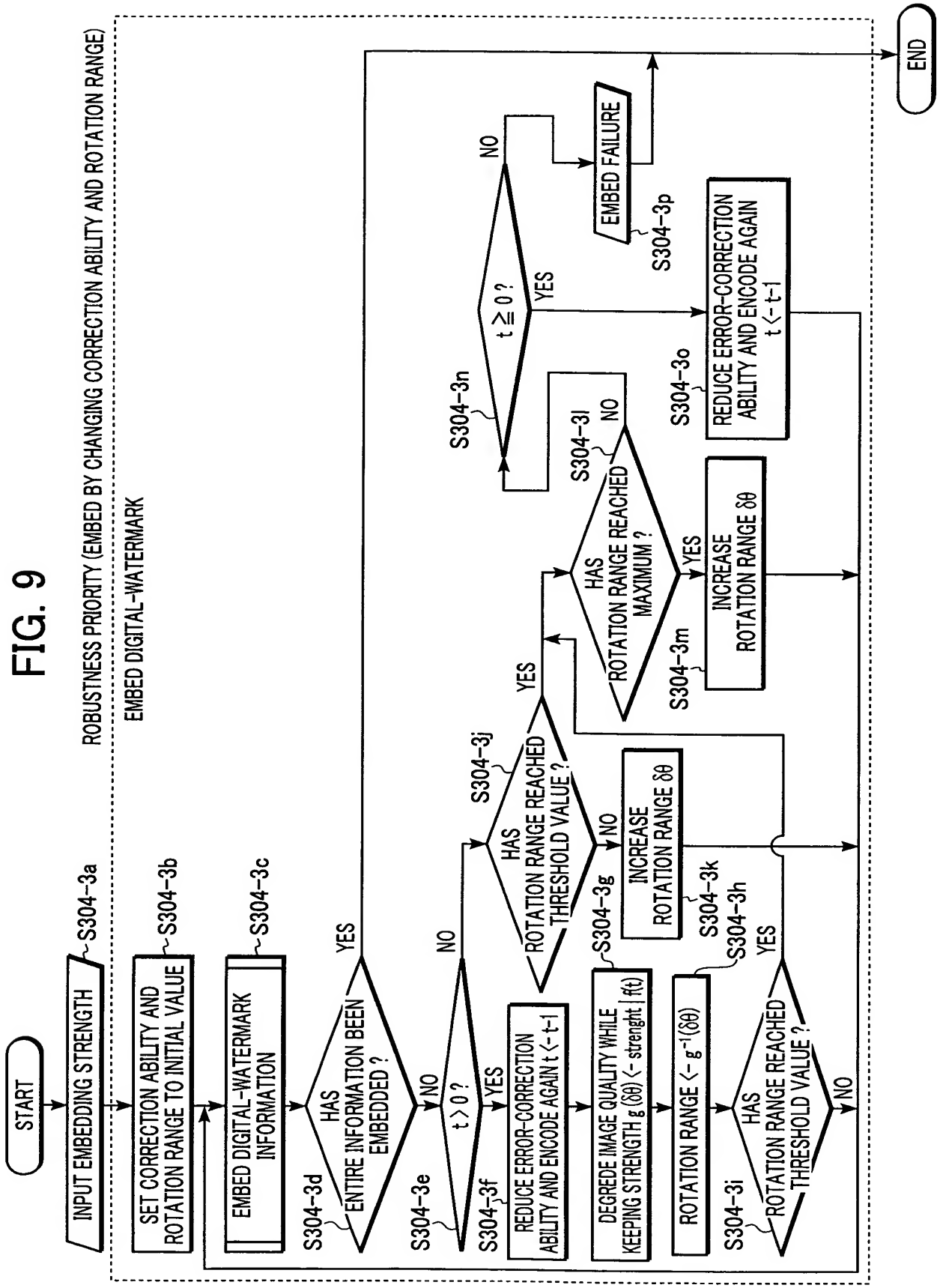

START
INPUT EMBEDDING STRENGTH
S304-3a
ROBUSTNESS PRIORITY (EMBED BY CHANGING CORRECTION ABILITY AND ROTATION RANGE)
SET CORRECTION ABILITY AND ROTATION RANGE TO INITIAL VALUE
S304-3b
EMBED DIGITAL-WATERMARK
EMBED DIGITAL-WATERMARK INFORMATION
S304-3c
S304-3d
HAS ENTIRE INFORMATION BEEN EMBEDDED ?
YES
NO
S304-3e
t > 0 ?
NO
YES
S304-3f
REDUCE ERROR-CORRECTION ABILITY AND ENCODE AGAIN t <- t-1
S304-3j
HAS ROTATION RANGE REACHED THRESHOLD VALUE ?
YES
NO
S304-3g
DEGREDE IMAGE QUALITY WHILE KEEPING STRENGTH g(δθ) <- strength | f(t)
INCREASE ROTATION RANGE δθ
S304-3k
ROTATION RANGE <- g^-1(δθ)
S304-3h
S304-3i
HAS ROTATION RANGE REACHED THRESHOLD VALUE ?
YES
NO
S304-3l
HAS ROTATION RANGE MAXIMUM ?
YES
NO
S304-3m
INCREASE ROTATION RANGE δθ
S304-3n
t ≧ 0 ?
YES
NO
S304-3o
REDUCE ERROR-CORRECTION ABILITY AND ENCODE AGAIN t <- t-1
S304-3p
EMBED FAILURE
END

FIG. 10

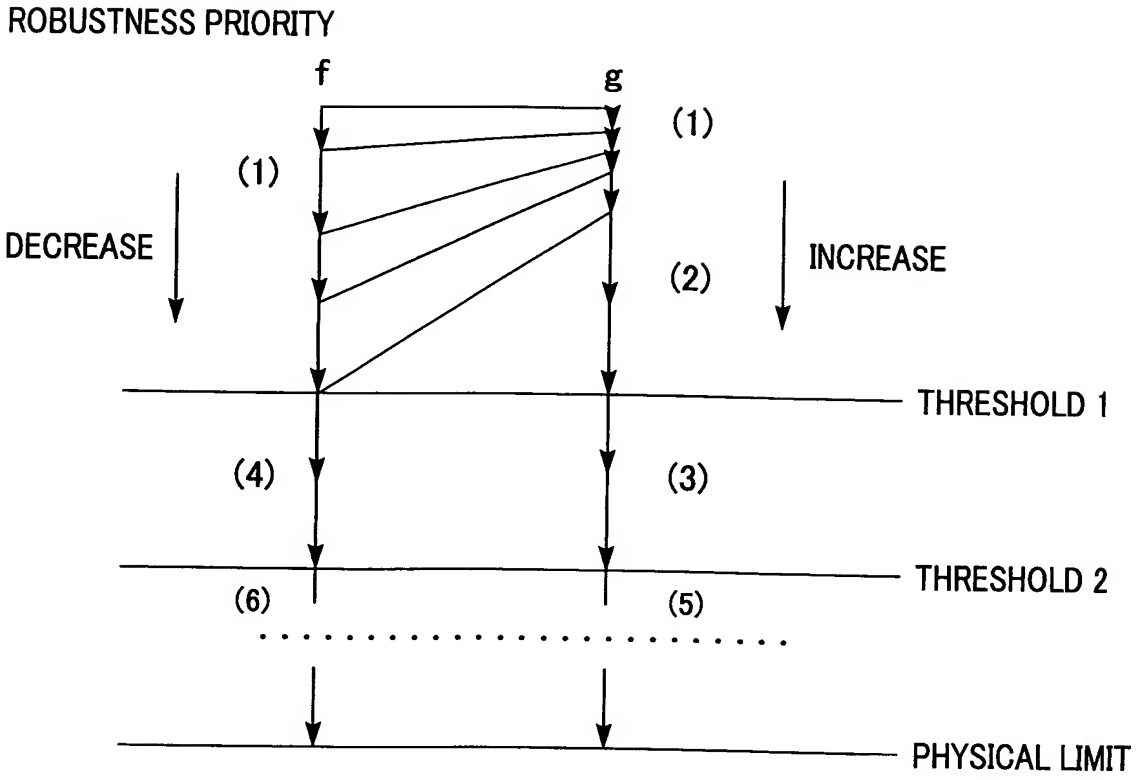

ROBUSTNESS PRIORITY
f
g
(1)
(1)
DECREASE
(2)
INCREASE
THRESHOLD 1
(4)
(3)
THRESHOLD 2
(6)
(5)
PHYSICAL LIMIT

FIG. 11

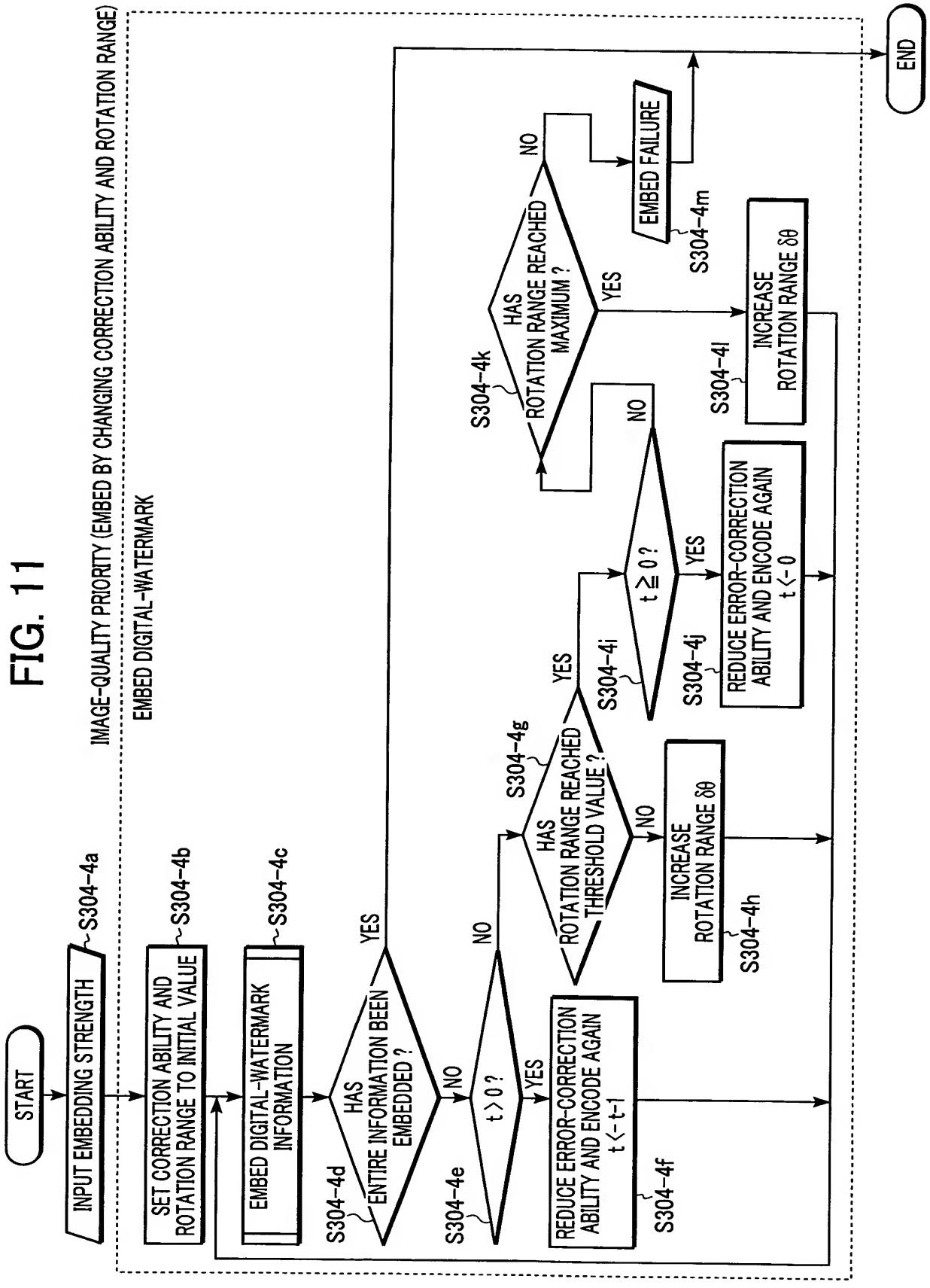

START
INPUT EMBEDDING STRENGTH
S304-4a
IMAGE-QUALITY PRIORITY (EMBED BY CHANGING CORRECTION ABILITY AND ROTATION RANGE)
SET CORRECTION ABILITY AND ROTATION RANGE TO INITIAL VALUE
S304-4b
EMBED DIGITAL-WATERMARK
S304-4c
EMBED DIGITAL-WATERMARK INFORMATION
S304-4d
HAS ENTIRE INFORMATION BEEN EMBEDDED ?
YES
NO
S304-4e
t > 0 ?
NO
YES
S304-4g
HAS ROTATION RANGE REACHED THRESHOLD VALUE ?
YES
NO
S304-4i
t ≧ 0 ?
YES
NO
S304-4j
REDUCE ERROR-CORRECTION ABILITY AND ENCODE AGAIN
t <- 0
REDUCE ERROR-CORRECTION ABILITY AND ENCODE AGAIN
t <- t-1
S304-4f
INCREASE ROTATION RANGE δθ
S304-4h
S304-4k
HAS ROTATION RANGE REACHED MAXIMUM ?
YES
NO
S304-4l
INCREASE ROTATION RANGE δθ
EMBED FAILURE
S304-4m
END

FIG. 12

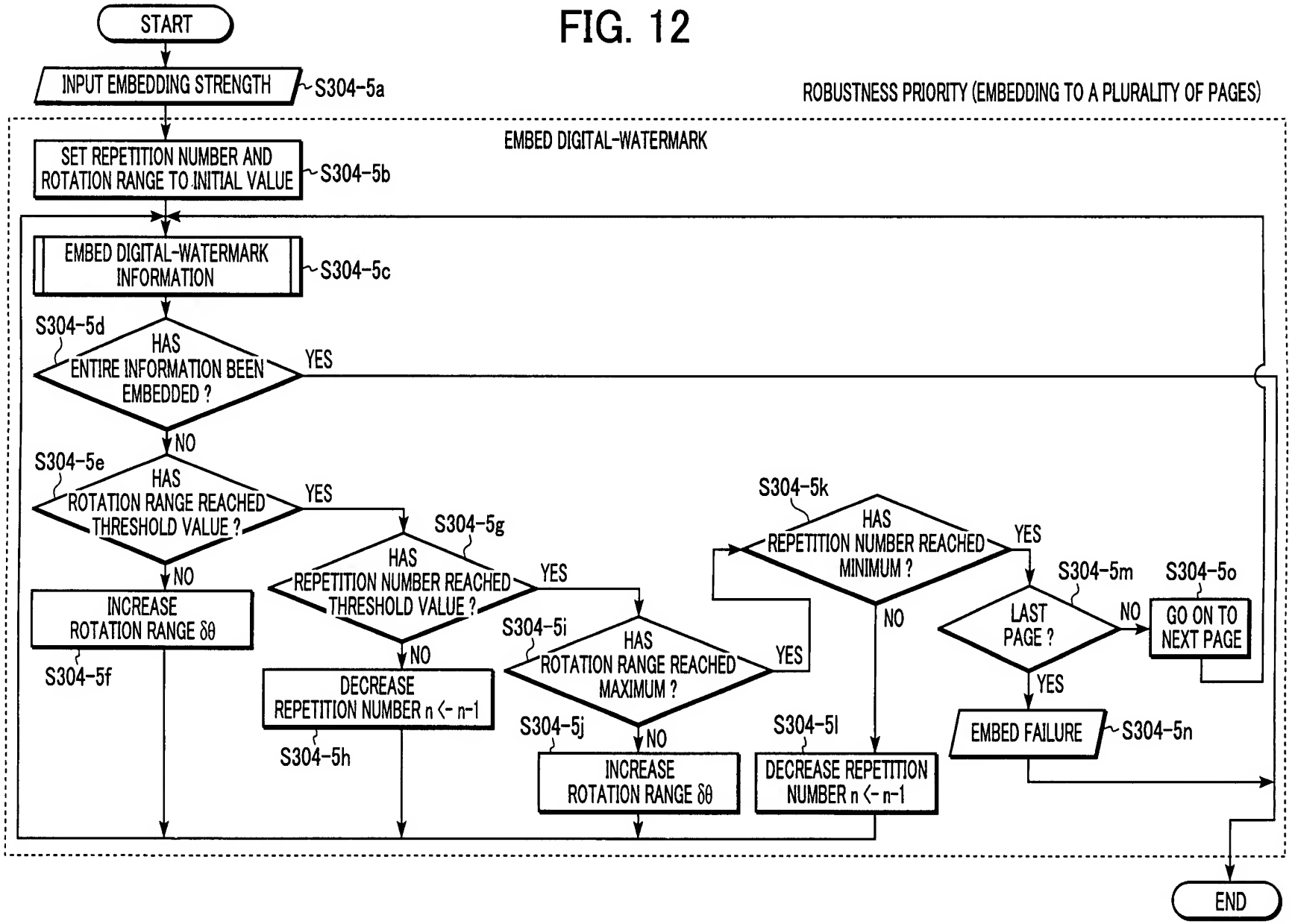

START
INPUT EMBEDDING STRENGTH
S304-5a
ROBUSTNESS PRIORITY (EMBEDDING TO A PLURALITY OF PAGES)
EMBED DIGITAL-WATERMARK
SET REPETITION NUMBER AND ROTATION RANGE TO INITIAL VALUE
S304-5b
EMBED DIGITAL-WATERMARK INFORMATION
S304-5c
S304-5d
HAS ENTIRE INFORMATION BEEN EMBEDDED ?
YES
NO
S304-5e
HAS ROTATION RANGE REACHED THRESHOLD VALUE ?
YES
NO
INCREASE ROTATION RANGE δθ
S304-5f
S304-5g
HAS REPETITION NUMBER REACHED THRESHOLD VALUE ?
YES
NO
DECREASE REPETITION NUMBER n <- n-1
S304-5h
S304-5i
HAS ROTATION RANGE REACHED MAXIMUM ?
YES
NO
S304-5j
INCREASE ROTATION RANGE δθ
S304-5k
HAS REPETITION NUMBER REACHED MINIMUM ?
YES
NO
S304-5l
DECREASE REPETITION NUMBER n <- n-1
S304-5m
LAST PAGE ?
NO
YES
S304-5o
GO ON TO NEXT PAGE
EMBED FAILURE
S304-5n
END

FIG. 13

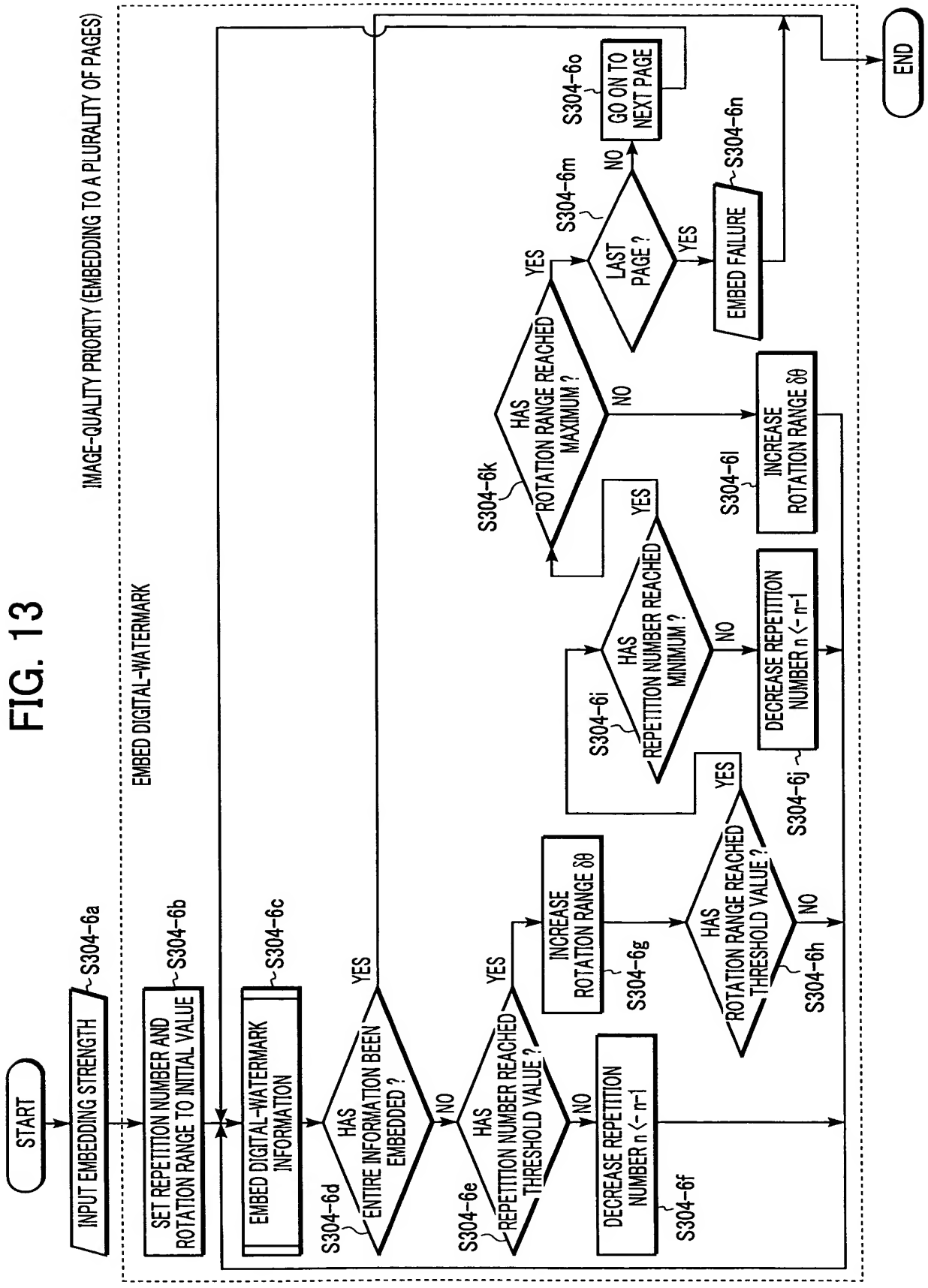

START
INPUT EMBEDDING STRENGTH
S304-6a
IMAGE-QUALITY PRIORITY (EMBEDDING TO A PLURALITY OF PAGES)
EMBED DIGITAL-WATERMARK
SET REPETITION NUMBER AND ROTATION RANGE TO INITIAL VALUE
S304-6b
EMBED DIGITAL-WATERMARK INFORMATION
S304-6c
S304-6d
HAS ENTIRE INFORMATION BEEN EMBEDDED ?
YES
NO
S304-6e
HAS REPETITION NUMBER REACHED THRESHOLD VALUE ?
YES
NO
INCREASE ROTATION RANGE δθ
S304-6g
DECREASE REPETITION NUMBER n <- n-1
S304-6f
HAS ROTATION RANGE REACHED THRESHOLD VALUE ?
S304-6h
YES
NO
S304-6i
HAS REPETITION NUMBER REACHED MINIMUM ?
YES
NO
DECREASE REPETITION NUMBER n <- n-1
S304-6j
S304-6k
HAS ROTATION RANGE REACHED MAXIMUM ?
YES
NO
INCREASE ROTATION RANGE δθ
S304-6l
S304-6m
LAST PAGE ?
YES
NO
EMBED FAILURE
S304-6n
GO ON TO NEXT PAGE
S304-6o
END

FIG. 14

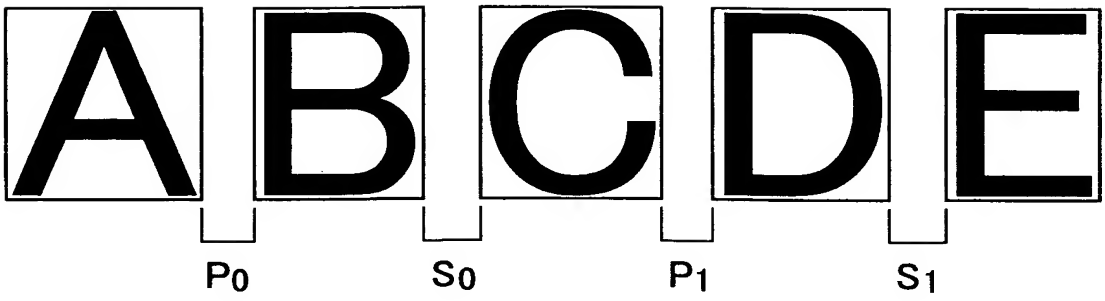


FIG. 15

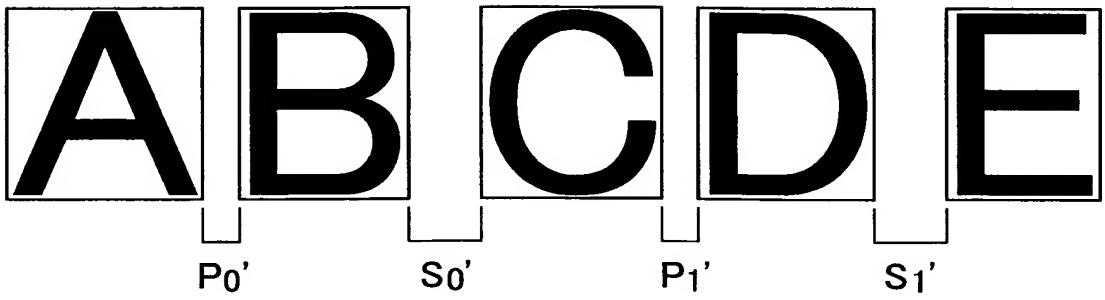


FIG. 16

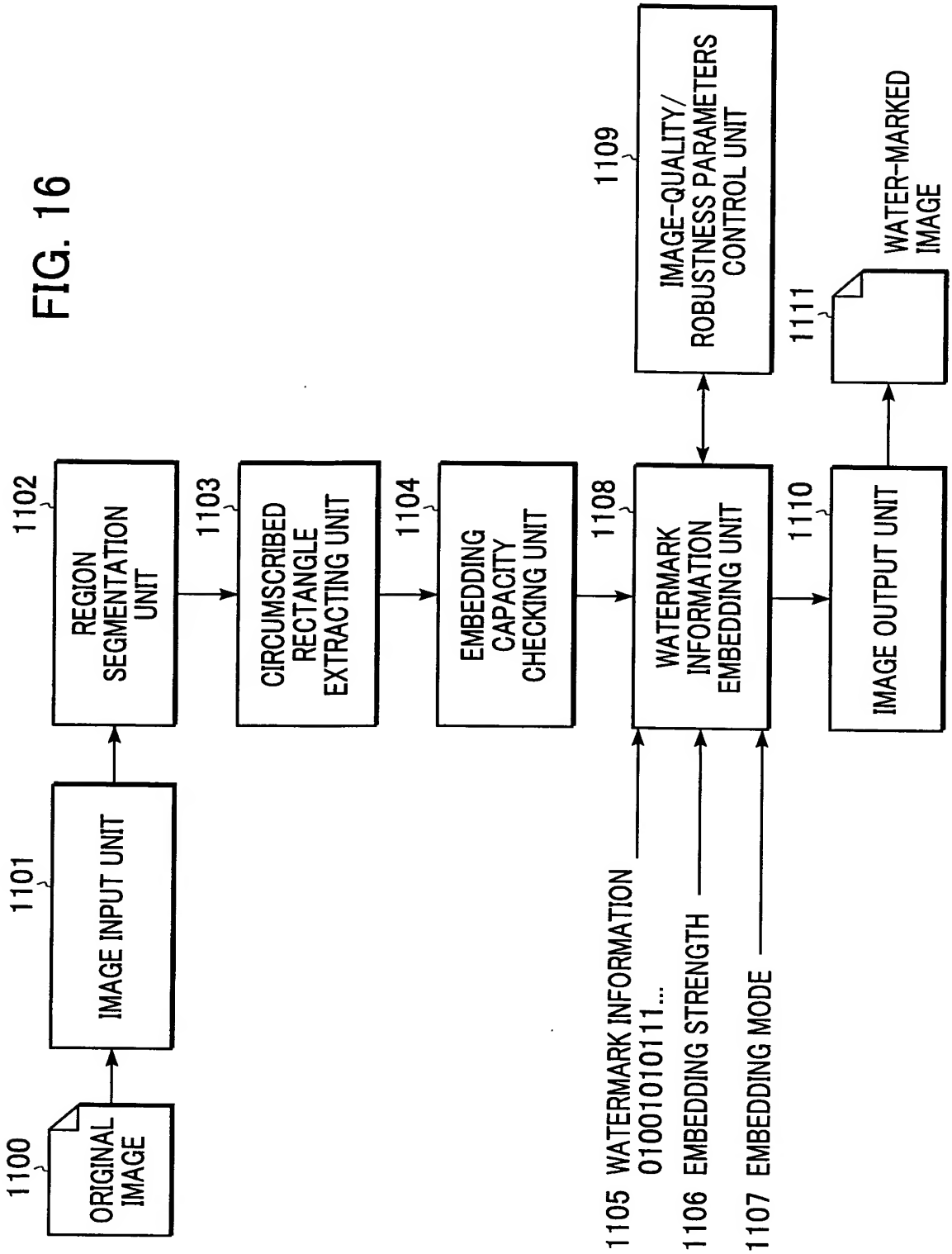

1100
ORIGINAL IMAGE
1101
IMAGE INPUT UNIT
1102
REGION SEGMENTATION UNIT
1103
CIRCUMSCRIBED RECTANGLE EXTRACTING UNIT
1104
EMBEDDING CAPACITY CHECKING UNIT
1105 WATERMARK INFORMATION
0100101011...
1106 EMBEDDING STRENGTH
1107 EMBEDDING MODE
1108
WATERMARK INFORMATION EMBEDDING UNIT
1109
IMAGE-QUALITY/ ROBUSTNESS PARAMETERS CONTROL UNIT
1110
IMAGE OUTPUT UNIT
1111
WATER-MARKED IMAGE

FIG. 17

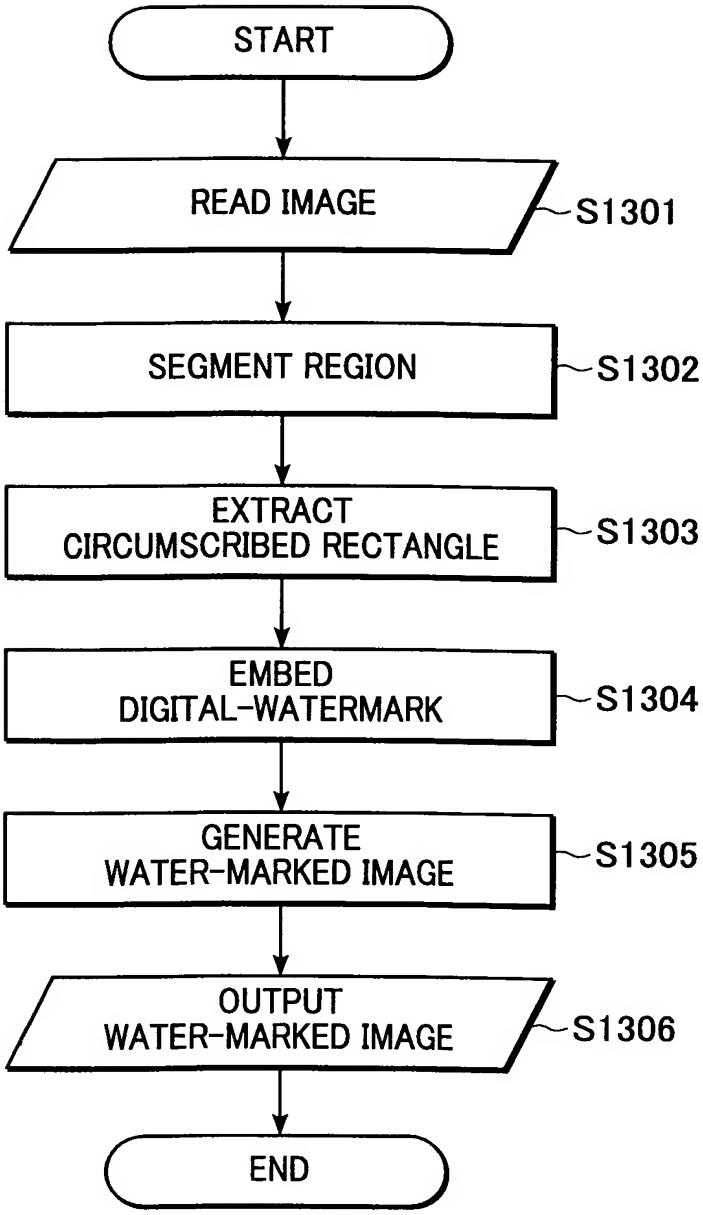

START
READ IMAGE
S1301
SEGMENT REGION
S1302
EXTRACT CIRCUMSCRIBED RECTANGLE
S1303
EMBED DIGITAL-WATERMARK
S1304
GENERATE WATER-MARKED IMAGE
S1305
OUTPUT WATER-MARKED IMAGE
S1306
END

FIG. 18

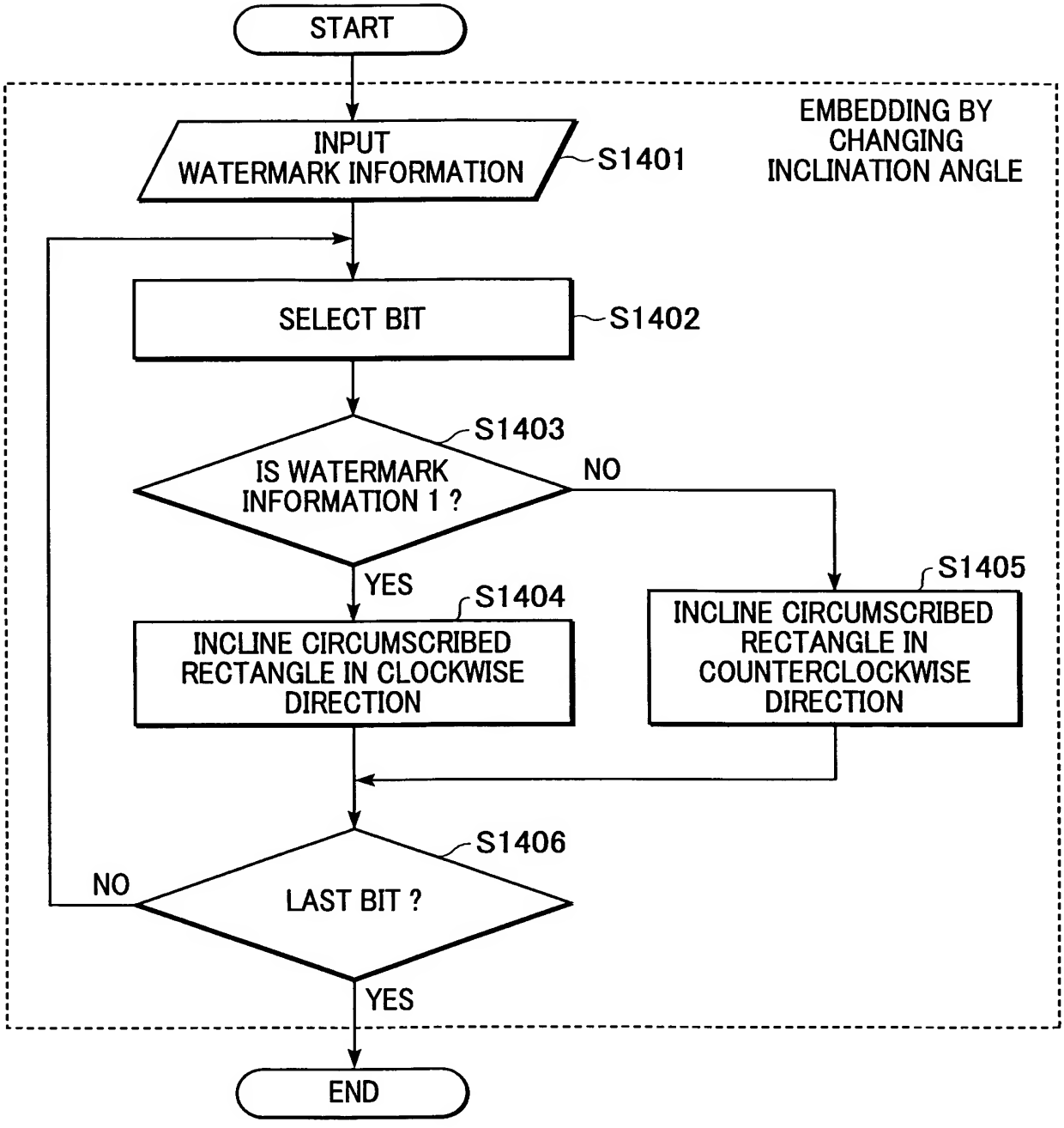

START
EMBEDDING BY CHANGING INCLINATION ANGLE
INPUT WATERMARK INFORMATION
S1401
SELECT BIT
S1402
S1403
IS WATERMARK INFORMATION 1 ?
NO
YES
S1404
INCLINE CIRCUMSCRIBED RECTANGLE IN CLOCKWISE DIRECTION
S1405
INCLINE CIRCUMSCRIBED RECTANGLE IN COUNTERCLOCKWISE DIRECTION
S1406
LAST BIT ?
NO
YES
END

FIG. 19

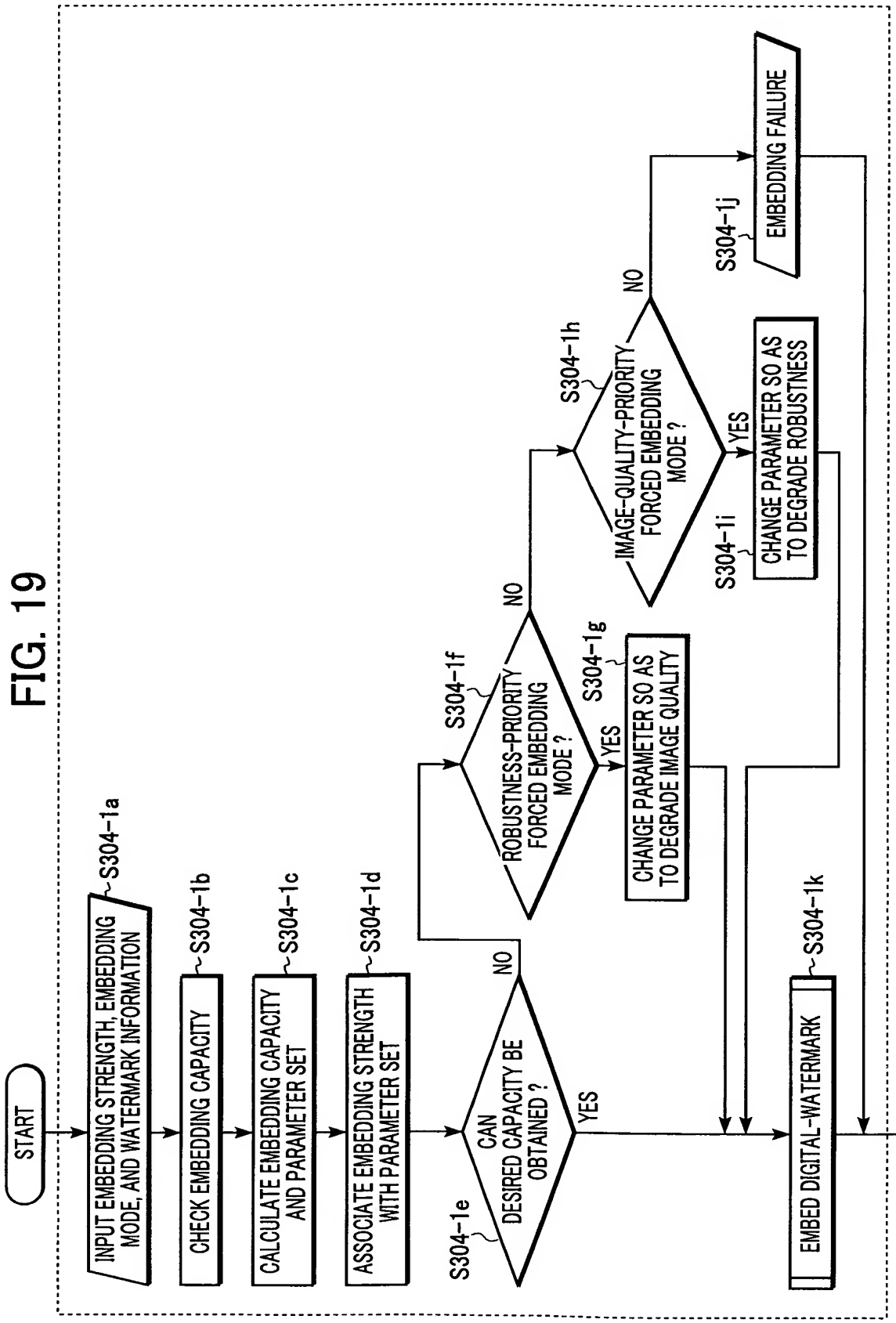

START
INPUT EMBEDDING STRENGTH, EMBEDDING MODE, AND WATERMARK INFORMATION
S304-1a
CHECK EMBEDDING CAPACITY
S304-1b
CALCULATE EMBEDDING CAPACITY AND PARAMETER SET
S304-1c
ASSOCIATE EMBEDDING STRENGTH WITH PARAMETER SET
S304-1d
S304-1e
CAN DESIRED CAPACITY BE OBTAINED ?
NO
YES
S304-1f
ROBUSTNESS-PRIORITY FORCED EMBEDDING MODE ?
NO
YES
S304-1g
CHANGE PARAMETER SO AS TO DEGRADE IMAGE QUALITY
S304-1h
IMAGE-QUALITY-PRIORITY FORCED EMBEDDING MODE ?
NO
YES
S304-1i
CHANGE PARAMETER SO AS TO DEGRADE ROBUSTNESS
S304-1j
EMBEDDING FAILURE
S304-1k
EMBED DIGITAL-WATERMARK
END

FIG. 20

REPETITION NUMBER		IMAGE-QUALITY PARAMETER		EMBEDDING CAPACITY	
3 =	n_1	2 =	q_1	200	l_1
4		2		125	
5	n_2	2	q_2	76	l_2
6		2		61	
7	n_3	2	q_3	48	l_3
8		2		40	
9	n_4	2	q_4	33	l_4
10		2		28	
11	n_5	2	q_5	24	l_5
12		2		21	
13	n_6	2	q_6	18	l_6
14		2		15	
15	n_7	2	q_7	13	l_7
16		2		11	
17	n_8	2	q_8	9	l_8
18		2		8	
19	n_9	2	q_9	6	l_9
20		2		4	
21	n_{10}	2	q_{10}	3	l_{10}

FIG. 21

EMBEDDING STRENGTH	REPETITION NUMBER	IMAGE-QUALITY PARAMETER	EMBEDDING CAPACITY
1	n_1	q_1	l_1
2	n_2	q_2	l_2
3	n_3	q_3	l_3
4	n_4	q_4	l_4
5	n_5	q_5	l_5
6	n_6	q_6	l_6
7	n_7	q_7	l_7
8	n_8	q_8	l_8
9	n_9	q_9	l_9
10	n_{10}	q_{10}	l_{10}

FIG. 22

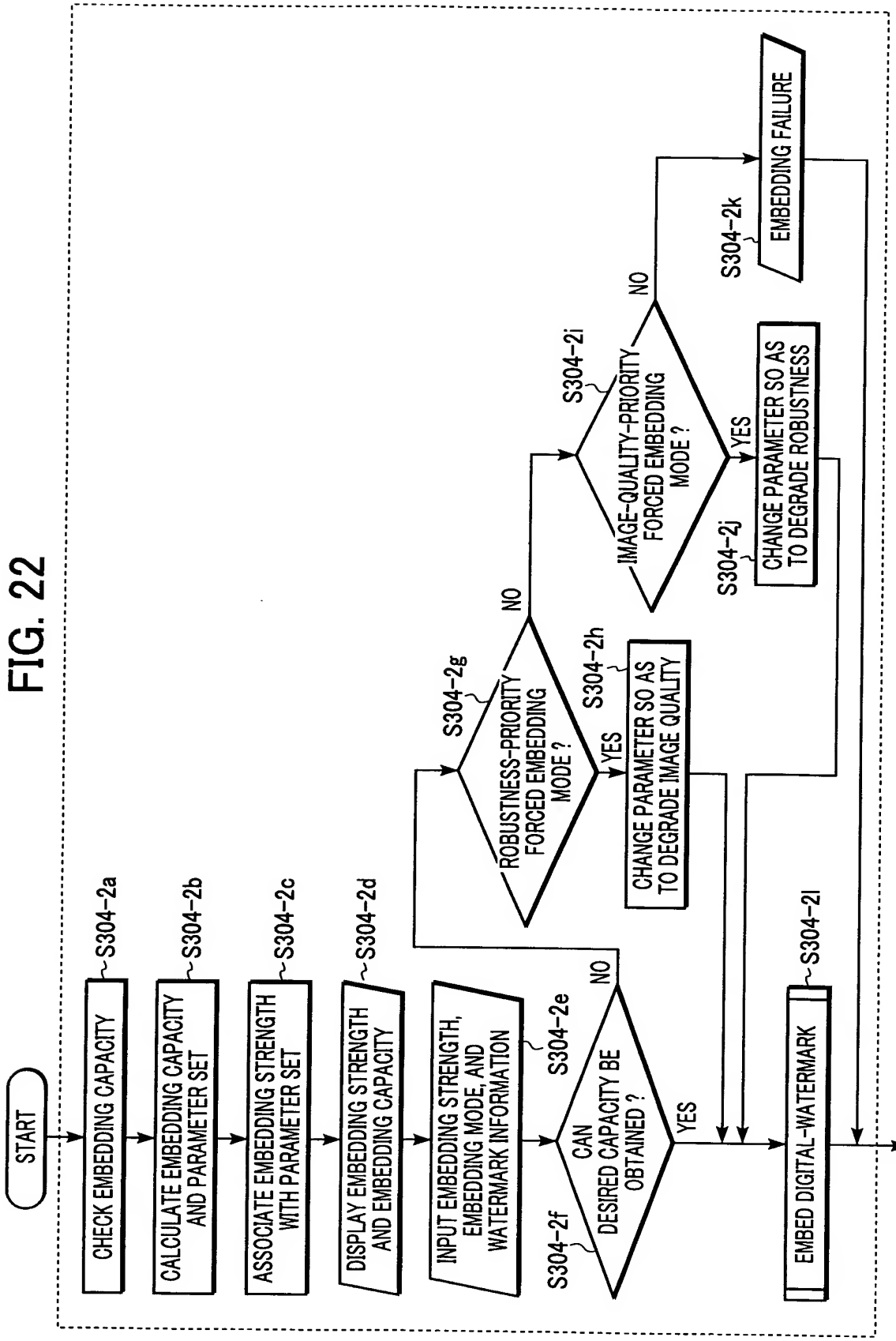
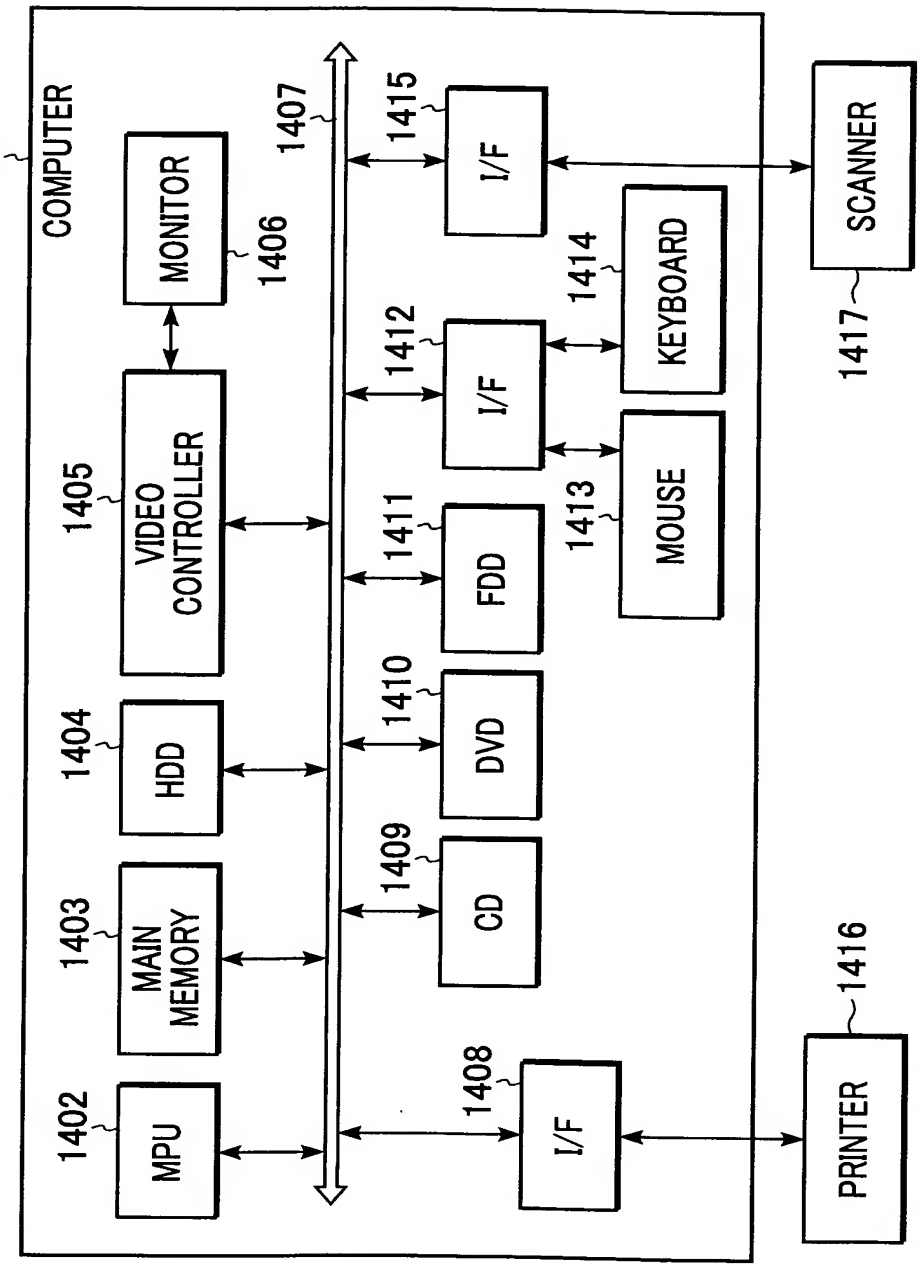

START
CHECK EMBEDDING CAPACITY
S304-2a
CALCULATE EMBEDDING CAPACITY AND PARAMETER SET
S304-2b
ASSOCIATE EMBEDDING STRENGTH WITH PARAMETER SET
S304-2c
DISPLAY EMBEDDING STRENGTH AND EMBEDDING CAPACITY
S304-2d
INPUT EMBEDDING STRENGTH, EMBEDDING MODE, AND WATERMARK INFORMATION
S304-2e
CAN DESIRED CAPACITY BE OBTAINED ?
S304-2f
NO
YES
ROBUSTNESS-PRIORITY FORCED EMBEDDING MODE ?
S304-2g
NO
YES
CHANGE PARAMETER SO AS TO DEGRADE IMAGE QUALITY
S304-2h
IMAGE-QUALITY-PRIORITY FORCED EMBEDDING MODE ?
S304-2i
NO
YES
CHANGE PARAMETER SO AS TO DEGRADE ROBUSTNESS
S304-2j
EMBEDDING FAILURE
S304-2k
EMBED DIGITAL-WATERMARK
S304-2l
END

FIG. 23


1401
COMPUTER
1402
MPU
1403
MAIN MEMORY
1404
HDD
1405
VIDEO CONTROLLER
1406
MONITOR
1407
1408
I/F
1409
CD
1410
DVD
1411
FDD
1412
I/F
1413
MOUSE
1414
KEYBOARD
1415
I/F
1416
PRINTER
1417
SCANNER

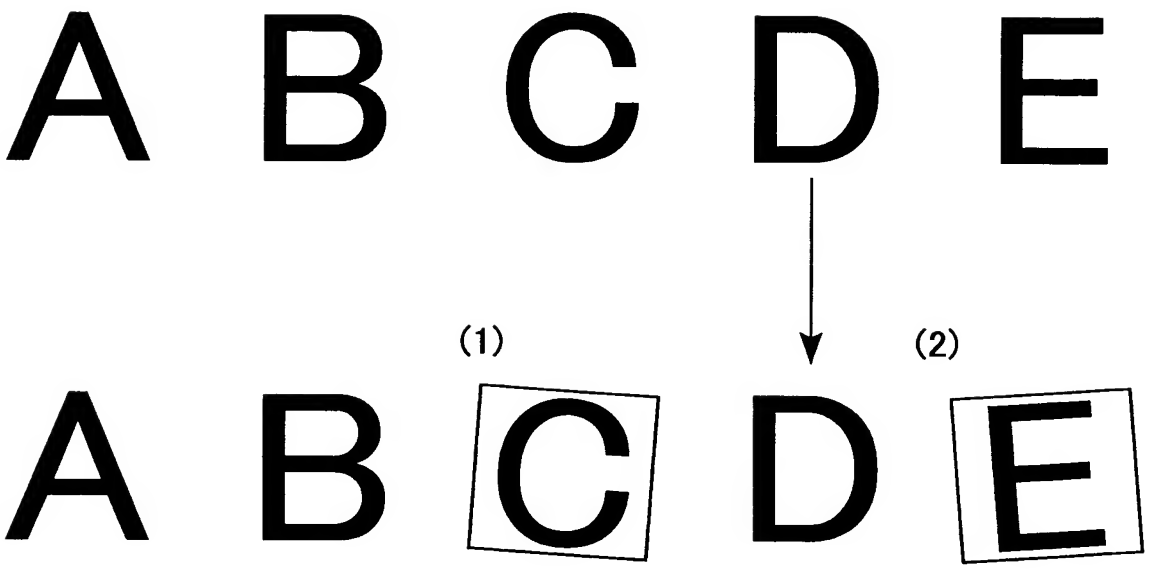



FIG. 24